

## Development of optical fiber Light-Transmitting Concrete (LTC): A narrative review.

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Page | 1

### Abstract

Light-transmitting concrete (LTC) containing optical fibers allows natural light to pass through structural elements while maintaining the mechanical characteristics of conventional concrete. This property offers potential applications in energy-efficient buildings, architectural façades, pavements, and infrastructure where daylight utilization is desirable. The present narrative review summarizes published research on optical fiber light-transmitting concrete, focusing on material composition, fabrication methods, optical performance, mechanical properties, durability, and microstructural characteristics.

Evidence from previous studies indicates that light transmission in LTC is strongly influenced by fiber parameters such as volume fraction, diameter, and spacing. Increased fiber content generally improves light transmittance, whereas larger fiber diameters and wider spacing tend to reduce transmission efficiency. Mechanical properties, particularly compressive and flexural strength, depend on the interaction between optical fibers and the cement matrix, where weak interfacial bonding and increased porosity may affect structural performance. Durability aspects, including water absorption, permeability, and environmental exposure, remain insufficiently investigated in the existing literature.

Although optical fiber LTC demonstrates promising architectural and energy-saving applications, challenges remain in fabrication complexity, cost, and long-term durability. Future research should address fiber–matrix interfacial behavior, standardized testing methods for optical performance, and optimization of fiber parameters to balance structural strength with light transmission efficiency.

**Keywords:** Light transmitting concrete, Optical fibers in concrete, Mechanical and optical performance, Energy efficient construction.

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### Introduction

Population growth and urbanization have led to the overexploitation of natural resources, erratic climate change, environmental pollution, and excessive energy consumption. Today, a large part of the world's energy consumption comes from the building sector, which accounts for about 34% of the total global energy demand, of which 19% is used for lighting. With the increasing scarcity of land in towns and cities, buildings, such as high-rise buildings and underground buildings, are being developed in higher and deeper directions. The light environments inside these buildings basically rely on artificial lighting, which not only consumes a large amount of energy but also increases carbon dioxide emissions, indirectly causing a series of problems, such as the greenhouse effect. In addition, the shading from high-rise buildings significantly obstructs natural lighting in low-rise buildings. Indoor lighting can only be achieved through lighting energy consumption, so how to make full use of natural light and reduce lighting energy consumption was an issue of concern. To reduce light energy consumption and achieve sustainable buildings, new concrete materials, such as light-transmitting

concrete(LTC), have been invented and introduced into the construction industry. The light transmission effect of LTC can be applied to building facades to reduce building energy consumption; pavement to increase visibility and safety, and outdoor decorations in parks to add to their aesthetic appeal. Among the many light-guiding components, optical fibers can be used as sensors for structural health detection due to their excellent light transmission properties and high sensitivity. Optical fibers are arranged in parallel between the two outer surfaces of the concrete substrate to form a light-guiding channel; this arrangement has become the most commonly used material in the manufacture of LTCs. The most commonly used optical fibers in LTC are glass fiber and plastic fiber, both of which have excellent light transmission, but compared with glass fiber, plastic fiber costs less and is favored by researchers. Optical fiber LTCs have excellent light transmission properties, good structural characteristics, and variable decorative effects, which can make full use of external light sources, improve indoor visibility, and reduce light energy consumption in buildings. However, compared with traditional concrete structures, optical fiber LTC lacks widespread application in the construction industry, which may be due to the high

costs and complex fabrication process, as well as the lack of reliable data on mechanical properties, light transmission properties, and durability properties. However, the prepared optical fiber LTC still has some problems, such as a rough preparation process, insufficient light transmission, inadequate mechanical properties, poor durability, and single application scenarios, which seriously affect the application and promotion of fiber LTC. Although some researchers have attempted to improve the preparation process to improve its mechanical and durability properties, the data are relatively scattered and lacking. The data cannot provide theoretical guidance or reference significance for further study of transparent concrete. This manuscript reviews the research on the application of optical fiber LTC in building structures and infrastructures to explore its potential added value. The raw material selection, preparation process, performance testing, and analysis of optical fiber LTCs are discussed to provide a summary of the latest research progress and applications. The advantages and disadvantages are critically discussed to identify the research deficiencies and provide potential research directions for the future.

## Methodology

This study was conducted as a narrative review of published literature related to optical fiber light-transmitting concrete (LTC). Relevant studies were identified through electronic database searches including Scopus, Web of Science, ScienceDirect, and Google Scholar. The literature search focused on publications related to translucent concrete and optical fiber reinforced cementitious composites.

The following keywords and combinations were used during the search process: “*light-transmitting concrete*,” “*translucent concrete*,” “*optical fiber concrete*,” “*fiber optic concrete*,” “*transparent concrete*,” “*optical fiber reinforced cementitious composites*,” and “*daylighting concrete materials*.” Articles published between 2000 and 2024 were considered, since research on optical fiber-based translucent concrete has primarily developed during this period.

## Inclusion criteria

Studies were included if they:

- Investigated optical fiber or translucent concrete materials

- Reported light transmission properties, mechanical behavior, durability, or fabrication methods
- Were peer-reviewed journal articles, conference proceedings, or patents
- They were published in English

## Exclusion criteria

The following studies were excluded:

- Articles unrelated to cement-based translucent materials
- Publications focusing only on general optical fiber communication technology without application to concrete
- Non-scientific sources or articles lacking sufficient technical data

## Discussion

Relevant studies were examined and grouped according to major research themes, including material composition, preparation techniques, optical transmission characteristics, mechanical properties, durability behavior, and architectural applications. The selected literature was then synthesized qualitatively to summarize current knowledge and identify research gaps in the development of optical fiber light-transmitting concrete.

## Optical fiber

According to the core radius, the propagation mode of optical fibers can be divided into single-mode and multimode. The numerical aperture is a key indicator that affects the light transmission performance, which is closely related to the refractive index of the core. In general, multimode optical fibers have higher numerical apertures and are the preferred optical fibers in LTC. The most commonly used optical fibers in LTC are glass fibers and plastic fibers (PMMA, polymethylmethacrylate fibers). Table 1 presents a comparison of the raw materials, properties, and drawbacks of glass fiber and PMMA. Both types of fibers can achieve more than 90% in terms of light transmission; however, PMMA offers greater resistance to damage and is cheaper and easier to promote in the construction industry compared to glass fiber.

**Table1.Comparison between glass fiber and plastic fiber.**

Fiber Type	Materials	Performance	Defects
Glass fiber	Silicon and a little dopant	Long transmission distance	Large brittleness, poor mechanical strength, expensive
PMMA	The cladding is made of silicone and the core is made of polymethylmethacrylate	Good toughness, cheap, easy to install, and light weight	large attenuation, and poor heat resistance

Page | 3

Losonczy embedded optical fibers in concrete in 2001 and defined it as LTC. Since then, LTC has gradually become more widely recognized. The high light transmittance of optical fibers allows them to have excellent light-transmitting properties even when the angle of incidence of the light source exceeds 60°. The brittleness, poor mechanical strength, and high cost of glass optical fibers limit their application in the field of LTC. Therefore, plastic optical fibers, which are tough, less costly, and easy to install, have become alternatives to glass optical fibers. Researchers have used plastic optical fibers instead of glass fibers to study the effectiveness of light transmission properties, with fiber spacing and content being the main factors affecting the light transmission and mechanical properties of LTC. Some researchers and scholars have applied optical fiber LTC to building maintenance structures and determined the optimum acceptance angle of PMMA as 30° by numerical simulation. Optical fiber LTC can be used in construction as well as in road engineering, e.g., lane separators, sensors, etc., to improve traffic safety.

### Concrete

The cementitious material in concrete is generally based on silicate cement with some active admixtures. In addition, sulfate aluminum cement can be used as a cementitious material. Silicate cement has relatively high alkalinity, which can seriously erode glass optical fibers. It was recommended that alumina sulfate cement be used as a matrix for the preparation of optical fiber LTC because of its high early strength and low alkalinity compared to silicate cement. Alkali solution curing has a more obvious destructive effect on the strength of optical fiber LTC with silicate cement as the matrix, and alkali solution corrodes LTC to a much greater extent than salt solution. The choice of the aggregate for LTC was also very important. First of all, the maximum particle size of the aggregate should be controlled, generally not exceeding the fiber spacing; otherwise, it will cause difficulties in the distribution of the optical fiber. Generally, the choices are the cement net paste or formulations made with finer sand. Secondly, the aggregate particle size distribution and volume ratio should be considered to ensure that there is a large degree of mobility without water secretion to achieve self-compacting and to ensure that the system material itself has good volume stability and high strength. In addition, high fluid, self-compacting, and low-alkalinity cementitious materials should be prepared

by adjusting the type of admixture, content, and water-cement ratio to ensure that the matrix material itself has good volume stability and strength characteristics. The microstructural and mechanical properties of concrete are directly related to the macroscopic properties of optical fiber LTC. According to the implantation order of the optical fiber, the preparation process of optical fiber LTC can be divided into the first-implantation method and the post-implantation method. The 'first implantation method' involves inserting the optical fiber into the forming mold, fixing it in place, pouring fine-grained concrete, cement mortar, or cement, and then cutting it to obtain the required product after curing and achieving a certain degree of strength. To ensure the orderly implantation of optical fibers, Liet all. introduced the application of fiber textile technology for the preparation of optical fiber LTCs. The preparation method involves weaving optical fibers into a single-layer fabric, where the optical fibers are placed in a unidirectional direction, and each end of the optical fibers is connected by cotton yarns. The stable spacing of the optical fibers should be between 3 and 6 mm. Then, the fibers are fixed using a specific method and poured with cement mortar. Roy et al. also used textile optical fibers to prepare optical fiber LTCs to reduce the workload during the preparation process, unlike Li et al. The fiber-optic fabrics are inserted layer by layer (according to the designed distances during the concrete pouring process, without the need for pre-fixing). Due to the cumbersome textile process of optical fibers, a method was developed to simplify the implantation of optical fibers. Altomate inserted optical fibers of a specific length into the holes of the prefabricated formwork. The cementitious material is then poured so that the optical fibers are embedded in the concrete, avoiding the tedious textile fixation process. To address the issue of fixing the positions of the fibers, the authors designed a set of production molds used to reduce the disturbance of the fibers by the cement paste during the pouring process; the production molds could be used to produce light-transmitting concrete with different sizes or shapes according to the different needs of the design. Mahdi prepared cubic samples of 100×100×100mm<sup>3</sup> and cylindrical samples with dimensions of 200×100 mm for his experiments on the study of the properties of light-transmitting concrete. When preparing the molds, the number of holes required for the fibers on the wooden boards was first designed based on the dosage and diameter of the fibers. Then, the fibers were perforated and fixed, and finally, the cementitious composite was

poured. The first implantation method has the advantages of one-time casting, uniform distribution of optical fibers, and stable mechanical properties, but there are also problems, such as difficulty in fixing optical fibers and the poor light transmission of optical fibers due to alkali corrosion, both of which affect the performance and application of the material. The 'post-implantation method' involves pouring cement concrete products first, and then drilling holes to implant the optical fiber to obtain the required products. Compared to the first planting method, the latter method is relatively simple and easy to implement. The position of the optical fiber is fixed via drilling holes, and the light-transmitting effect is great. But because the optical fiber is implanted at a later stage, the bond between the surface of the optical fiber and the cement substrate is not firm, which affects the durability of the optical fiber LTC. In addition to the above two methods, some scholars have also proposed a new preparation method—the paving method. Pouring and laying are repeated until the whole mold is paved, and then, after a period of maintenance, the LTC with ideal shapes is obtained via cutting and sanding. Each of the three pouring methods has its advantages and disadvantages. The first-implantation method can effectively maintain the stability of optical fiber transmittance, reduce the impact of the cement paste on the optical fiber, and then achieve the pre-designed light-transmitting effect. At the same time, through the design of molds tailored to different needs, it is possible to produce different specifications or shapes of light-transmitting concrete. The post-implantation method can better fix the position of the optical fiber; the operation is simple and widely applicable, and compared with the first planting method, its light transmission effect is better. However, issues such as poor bonding of optical and aggregate fiber, as well as the corrosion of optical fibers by the alkaline environment of concrete, reduce the durability and light transmission effect of the light guide. This needs to be further studied in depth. For example, the location and accuracy of the drilled holes require a high degree of precision, and the effects of hole defects on the relevant properties of concrete need to be further investigated. The paving method optimizes the first-implantation method and the post-implantation method to fix the position of the optical fiber, but the optical fiber textile is to cumbersome, and the cement paste easily causes the textile to be misaligned or deformed during the layered paving and pouring process, thus affecting the effect of light transmittance and the mechanical properties of the concrete. Therefore, in the actual preparation process, the first-implantation method is mostly used to minimize the impact on the light transmission effect and physical and mechanical properties. In this section, the research results of optical fiber LTC will be reviewed from four aspects: light transmission properties, mechanical properties, durability properties, and microstructural analysis.

At present, there are no corresponding standards to refer to for the light transmission test of optical fiber LTC, and

researchers have used different experimental condition settings and test equipment. Henriques et al. made a closed dark box for the light transmission test to prevent interference from external light sources, which also ensured that the test light source directed all the light toward the sample. Most researchers have carried out tests on the transmittance of LTC under the influence of different variables. The data were somewhat discrete and were due to the different fiber diameters, light power, distances, specimen sizes, and other conditions; however, researchers showed similar trends in the transmittance characteristics of the LTCs, with an increase in the fiber content leading to higher transmittance efficiencies. In addition to fiber content, the diameter and spacing of the fiber also affect the light transmission properties of optical fiber LTC. Tuam et al showed that the light transmission of LTC decreases with increasing fiber diameter. Chiewetal suggested that increasing fiber spacing decreases the light transmission of concrete. This is because more fibers with smaller diameters can be embedded in the same size LTC specimen compared to fibers with larger diameters; moreover, the superposition of light waves with coherent interference decreases with the increasing fiber spacing. It is worth noting that parameters such as fiber volume fraction, diameter, and spacing are interrelated with the light transmission performance of LTC. In general, the higher the fiber volume fraction, the higher the number of fibers and the reduced pitch. Similarly, the larger the fiber diameter, the higher the volume fraction when the fiber spacing and number are certain. Most previous studies were limited to the effect of fiber parameters (diameter, content, spacing) on LTC transmittance, but other environmental factors, such as light intensity, angle of incidence, and fiber aging should be taken into account; the roughness of the fiber ends also affects LTC transmittance performance because it leads to light scattering and reduces the intensity of light transmission. Compressive and flexural strengths are commonly used to evaluate the mechanical properties of optical fiber LTCs. Henriques also found a similar trend in their research. Through microanalysis, the gap between the fiber and mortar interface led to a reduction in compressive strength because the fiber surface was smooth, and the bond strength between the fiber and matrix interface was insufficient; the higher the content, the more defects in the weak zone. The authors also found that the difference in compressive strength was not significant between 0 and 2% fiber content, and concrete with fiber content greater than 5% was difficult to pour. However, Altomate and Kumar came up with opposite findings. Kumar concluded that the compressive strength of LTC increased with the increase in the volume of fiber-optic admixture but remained lower than the compressive strength of unadulterated fiber-optic concrete. Altomate found that the compressive strength of optical fiber LTC increased with the increased fiber content and was also higher than that of undoped optical fiber concrete, as a result of the combined effect of fiber spacing and the fiber diameter. This is because optical fibers with larger

diameters are stiffer and can help withstand compressive loads as compared to smaller diameters. This is because thicker fibers lead to an increase in the area of the interfacial weak zone, negatively affecting the compressive strength. Tested the compressive strength, flexural strength, and flexural toughness of optical fiber LTC. The flexural toughness of optical fiber LTC was 12% higher than that of plain concrete, indicating that optical fiber LTC possesses better ductility. It was found that the addition of optical fiber can increase the bending strength of the cement matrix, which may be related to the increased toughness of the system due to the optical fiber. As mentioned earlier, current studies have only focused on the effect of single factors such as fiber content, fiber cross-sectional area, and fiber arrangement on LTC performance, while the effect of optical fibers on LTC performance (under the coupling condition as well as other factors) has rarely been studied. In addition, due to the smooth and hydrophobic surface of the optical fiber, there was a weak zone at the optical fiber–cement matrix interface, and the interfacial bond strength will affect the mechanical properties of the optical fiber LTC. treated the surface of PMMA optical fibers with silane coupling agents to improve the strength of the optical fiber–substrate interface. Moreover, there are few studies on the bond strength of the fiber–matrix interface. To improve the mechanical strength of LTC, measures to improve the bond strength of the optical fiber–matrix interface need to be further investigated. Studies on the durability properties of optical fiber LTC have focused on permeability, porosity, and water absorption tests of light-transmitting concrete. investigated the water absorption properties of light-transmitting concrete with 2%, 3.5%, and 5% fiber additions, which increased by 309%, 345%, and 400%, respectively, with respect to plain concrete. The fiber incorporation increased the porosity of the samples. Conducted durability tests on fiber-optic LTCs under various conditions, including freeze–thaw, fading, chemical attack, water absorption, and permeability experiments. Investigated the effect of reagent concentration on the chemical attack resistance of fiber-optic LTCs. It was found that the permeation resistance of optical fiber LTC gradually decreased with the increase in fiber content, but the permeation resistance of optical fiber LTC was enhanced by using an epoxy resin surface treatment. Overall, less research has been conducted on durability testing compared to the mechanical and light transmission properties of optical fiber LTC, but the durability of optical fiber LTCs is critical, as it determines the sustainability of optical fiber LTCs in resisting deterioration and maintaining light transmission efficiency throughout their service life. This is due to the weaker interfacial bond between the optical fiber and concrete, which creates more pores within the concrete, providing invasion channels for aqueous solutions and chemical reagents. In addition to this, optical fiber LTCs, when used as enclosures for long-term outdoor exposure, are susceptible to weathering, UV radiation, acid rain erosion, and freeze–thaw action; studies on this range of

durability properties have not yet been reported. The strength and durability of optical fiber LTC are macroscopic manifestations of its microstructure. Currently, only a few researchers have conducted microstructural analysis of optical fiber LTC. This gap contributed to a decrease in the compressive strength of the optical fiber LTC with the increase in the content of the optical fiber treated the optical fiber surface with a coupling agent, which was roughened by the presence of coupling material and was tightly bonded to the concrete matrix. Therefore, it is important to focus on the microstructures of optical fiber LTCs when researching the properties of optical fiber LTCs to determine the relationship between the microstructures of optical fiber LTCs and their mechanical and durability properties (and, thus, determine the countermeasures to improve their strength and durability properties). As a new type of building material, LTC provides a lot of inspiration for architectural designers by virtue of its excellent light transmittance performance and varied artistic effects. Designers and research and development institutes at home and abroad have widely used LTC in various architectural fields. Franco Church (2004) This was the first attempt at fiber-optic translucent concrete in architectural applications, the exterior walls of the church were made of translucent concrete bricks, and the sun's rays entered the interior after passing through the 50cm-thick brick wall, creating a comfortable light environment for the interior of the church, reducing lighting, and breaking the feeling of the traditional wall as being rough, bulky, and gloomy. The Capital Bank in Jordan uses light-transmitting precast concrete panels for the bank facade. At night, the lights inside the building are transmitted outside through the translucent concrete, bringing life to the whole building. The Italian Pavilion at the Shanghai World Expo was constructed with translucent concrete, with 40% coverage on the façade and 30% light transmission. Optical fiber LTC has been used for exterior walls, interior partitions, decorative walls, etc. It not only improves the level of indoor lighting but also creates a warm and comfortable atmosphere for the interior. It exhibits heat preservation, heat insulation, and sound insulation effects. Many companies at home and abroad have already brought the production of transparent concrete into practical applications, bringing convenience to people's lives as well as creating visual shock. Notable companies include Italcementi Group, Litracon, Luccon, Beijing Sapphire, Guangdong Xihe, Shenzhen Sanyu, and other new material technology companies. They produced a variety of LTC products that have been successfully used on a variety of occasions, not only as decorative wall panels but also for the floor, ceiling, stairs, desks, partition walls, bars, logos, and so on. Sapphire Corporation Ltd., in 2019, showcased a translucent concrete pavement at the World Park. Due to its good light transmittance, translucent concrete can be used for pavement decoration, and can also be applied to vehicle runways, airfield runways, and other places that can be used to guide the direction for vehicles and aircraft

in the evening or in bad weather conditions, to ensure the safety of vehicles and people.

Optical fiber LTC bulk heads were used at the front doors of the homes so that indoor residents could see if they were being visited by an outside guest. The use of optical fiber LTC on the exterior walls of interior stairwells improves the safety of lift operation by providing illumination in the event of a power failure. The use of optical fiber LTC underneath pavements improves the safety of walking at night. Optical fiber LTC was used for park seats, which show a colorful effect at night under the illumination of lights, improving the ornamental effect. In the future, after fully grasping the data on the mechanical properties and durability of optical fiber LTC and appropriately reducing the manufacturing cost, the application field of optical fiber LTC will be even more extensive. The economy was an important factor affecting the promotion of optical fiber LTC applications. Optical fibers have high costs compared to resin and glass, especially glass fibers, and the use of plastic fibers can significantly reduce the production cost of LTC. In addition to the cost of raw materials, the manufacturing process and labor costs cannot be ignored, because the layout and installation of optical fiber are more cumbersome. Some found that the production cost of LTC was positively correlated with the volume content of the optical fiber, but this did not mean that a higher volume content of optical fiber would result in higher transmittance; the best transmittance was obtained when the volume doping of the fiber was 5%. Investigated the production cost of optical fiber LTC and the return on investment regarding energy saving. Overall, the economics of fiber-optic LTC are closely related to the production cost, preparation process, labor cost, and reduction of energy consumption, but existing studies on the economics of optical fiber LTC are more focused on production cost. The effects of the preparation process and labor cost on the economy are less convenient to count, while research on the effect of energy saving on the economy of optical fiber LTC is still lacking, and existing research on the economy focuses more on optical fiber LTC, while more research should be carried out on the effects of other transparent components (resin or glass) on the economy of LTC. The application of LTC will inevitably cause an increase in the level of indoor lighting and a decrease in artificial lighting time. A numerical simulation of the indoor light environment of optical fiber LTC to show that an LTC wall with a transmittance rate of 5% reduces the indoor energy consumption for artificial lighting by 16% compared to an impervious wall. However, whether this kind of light environment meets people's needs, chose lighting uniformity and lighting coefficients as the evaluation indices of indoor lighting quality, and the results showed that LTC lighting uniformity and the average lighting coefficient increased by 51% and 30% compared with opaque walls, and the light switch-off time increased from 23% to 39%. The thermal environment is also a key factor affecting the energy consumption of a building. The effect of LTC on

indoor cooling and heating loads at different time intervals, as well as lighting savings through a combination of experiments and simulations; the results showed that the energy consumption of a building can be reduced by 18% when the fiber content is 5.6%. In summary, current research on the indoor lighting and heating environment created by LTC is relatively small; this research has been mostly carried out by means of simulation. LTC acts as a new type of building material; in addition to meeting the demand for structural safety, it needs to meet energy consumption demands, and research on the analysis of energy consumption of optical fiber LTC needs to be expanded. The application of optical fiber light-transmitting concrete should be extended to infrastructural areas such as building structures, roads, and tunnels. The correlation between the mechanical properties of optical fiber light-transmitting concrete and the light-transmitting properties needs to be further studied. If a link between mechanical properties and light transmission is established, the loss of light transmission can be used to predict the safety of the structure and provide a technical tool for structural health monitoring. The existing optical fiber LTC preparation process is relatively cumbersome, leading to increased manpower costs and reduced efficiency. Developing automated equipment for the precise positioning of optical fibers within molds will further reduce production costs. The durability study of fiber-optic light-transmitting concrete needs to be expanded further, and attention should also be paid to the physical and mechanical properties of the optical fiber, surface roughness, and microstructure, as these properties affect the light-transmitting performance and mechanical properties of light-transmitting concrete. One must identify the reasons affecting its performance and take corresponding measures. In addition to the thermo-mechanical properties of light-transmitting concrete, attention should be paid to its energy-saving properties as a basis for building a design to meet the needs of life. Resin also has good light-transmitting properties and is much cheaper; a comparative study between fiber-optic light-transmitting concrete and resin light-transmitting concrete was necessary to obtain optimum light transmittance, energy savings, and cost-effectiveness.

Research on optical fiber light-transmitting concrete (LTC) has mainly focused on three performance domains: optical transmission, mechanical behavior, and durability. Although several experimental investigations have been conducted, reported findings are not always consistent because of differences in specimen preparation, fiber characteristics, and matrix composition.

Most studies agree that fiber volume fraction, spacing, and diameter strongly influence light transmission efficiency. Chiew et al. and Tahwia et al. reported that increasing fiber content significantly improves light transmittance because a greater number of fibers creates additional channels for light propagation. Similar observations were reported by Huang and Li, who demonstrated that higher fiber density increases the overall luminous flux passing

through the concrete panel. However, other studies have shown that excessive fiber content may cause irregular fiber distribution and internal voids, which can reduce effective light transmission. These variations indicate that optimal transmittance depends not only on fiber content but also on the geometric arrangement and alignment of fibers during casting.

Mechanical performance results show greater variability among studies. Henriques et al. observed a reduction in compressive strength when optical fiber volume increased, attributing the decrease to weak bonding at the fiber–cement interface and the formation of interfacial voids. In contrast, Kumar and Altomate reported slight increases in compressive strength when larger-diameter fibers were used. These contrasting findings may be explained by differences in fiber stiffness, diameter, and spacing. Larger fibers can contribute to load transfer and crack bridging, whereas smaller fibers may act as defects when the interfacial bond with the cement matrix is insufficient. Surface treatments, such as silane coupling agents, have been shown to improve interfacial bonding and partially mitigate strength loss.

Durability performance has received comparatively less attention. Available studies indicate that increasing fiber content tends to increase porosity and water absorption, which may negatively affect long-term durability. For example, experimental work on water absorption reported significant increases when fiber content exceeded 3–5%, indicating that fiber insertion creates microchannels within the concrete matrix. Epoxy surface treatments and optimized fiber alignment have been proposed as strategies to improve resistance to permeability and chemical attack. Despite these efforts, long-term durability under environmental conditions such as freeze–thaw cycles, ultraviolet radiation, and chemical exposure remains insufficiently investigated.

Another area of discussion concerns the economic feasibility of LTC. Optical fibers represent a major component of the total production cost, especially when glass fibers are used. Studies comparing glass and plastic optical fibers indicate that polymer fibers provide a more cost-effective alternative while maintaining adequate optical performance. Numerical simulations have also suggested that translucent concrete panels can reduce artificial lighting energy consumption by approximately 16–18% in building interiors. However, most economic analyses rely on simulations rather than full-scale field studies, which limits the accuracy of cost–benefit assessments.

Taken together, the existing literature demonstrates that LTC has significant potential for architectural and infrastructure applications. At the same time, the variability of reported experimental results highlights the need for standardized preparation techniques, improved fiber–matrix bonding strategies, and systematic durability investigations.

## Conclusion

Optical fiber light-transmitting concrete represents an innovative construction material capable of combining structural performance with daylight transmission. The integration of optical fibers within cementitious matrices enables natural light to penetrate structural elements, which can reduce reliance on artificial lighting and improve architectural aesthetics.

Current research indicates that fiber volume fraction, diameter, and spacing are the primary parameters controlling light transmission efficiency. Increasing fiber content generally improves transmittance; however, excessive fiber incorporation may weaken the cement matrix and reduce compressive strength due to weak interfacial bonding and increased porosity. Mechanical performance, therefore, depends on achieving a balance between optical functionality and structural integrity.

Despite considerable progress, several important research gaps remain. First, there is no standardized testing method for evaluating the optical performance of LTC, which makes comparisons between studies difficult. Second, the interfacial bond between optical fibers and the cement matrix requires further investigation, particularly with respect to surface treatment techniques and fiber coatings that could improve load transfer and durability. Third, long-term durability under environmental conditions such as freeze–thaw cycles, ultraviolet radiation, chemical attack, and moisture exposure has not been sufficiently studied.

Future research should also focus on integrating material optimization with large-scale structural applications. Experimental studies on full-scale façade panels, pavements, and infrastructure components would provide more reliable data on structural behavior and durability in real operating conditions. In addition, the development of automated fabrication techniques for precise fiber alignment may reduce production costs and improve manufacturing efficiency.

From a practical perspective, LTC offers promising applications in building façades, interior partitions, pavements, tunnels, and architectural installations where natural lighting can enhance energy efficiency and visual aesthetics. With continued improvements in manufacturing methods, durability performance, and cost reduction, optical fiber light-transmitting concrete has the potential to become a viable material for sustainable construction and energy-efficient building design.

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### List of abbreviations

<b>LTC</b>	Light-Transmitting Concrete
<b>PMMA</b>	Polymethyl Methacrylate
<b>POF</b>	Plastic Optical Fiber
<b>LED</b>	Light Emitting Diode
<b>SCC</b>	Self-Compacting Concrete
<b>UV</b>	Ultraviolet

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### Conflict of interest

The authors declare no conflict of interest related to this work.

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### Data availability statement

This study is a narrative review based on previously published literature. No new experimental data were generated. All information used in this study is available in the cited references.

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